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# SHAKE TABLE TESTS OF MULTIPLE NON-STRUCTURAL ELEMENTS IN A LOW-DAMAGE STRUCTURAL STEEL BUILDING

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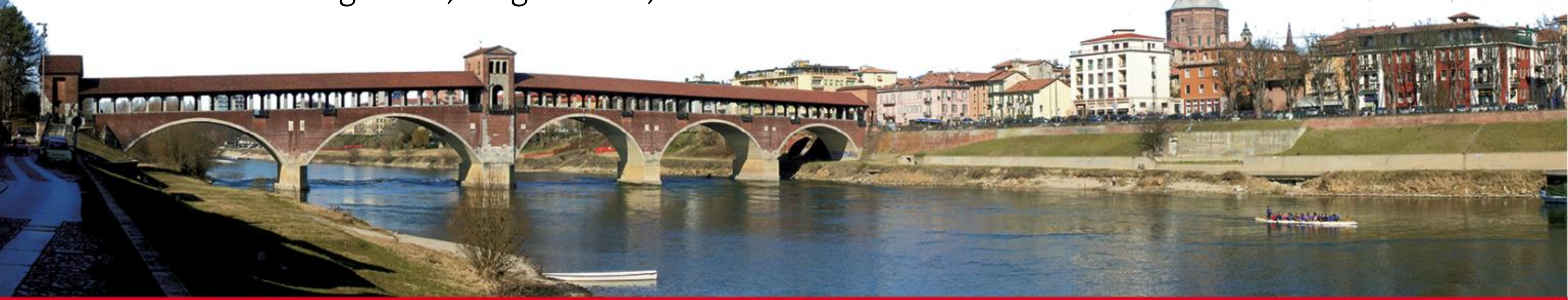

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# OUTLINE

- Introduction
- Scope
- Details of Test Non-Structural Elements
- Questions

# INTRODUCTION

*What if a building is designed such that the structure (frame, load bearing walls, floors) is damage-resistant but the non-structural components are fragile?*

**All our efforts may save only a small portion of the total loss**

**(In Christchurch, several houses had little structural damage, but still incurred substantial insurance/EQC claim)**

## Building value disaggregation

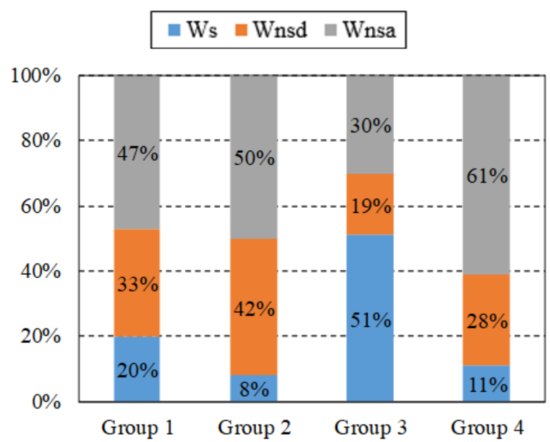
**Group 1**
Administration* Banks
Educational* Hospitality*
Industrial* Multiple Units
Offices Retail* Sports Halls

**Group 2**
Ancillary Facilities* Devotional Buildings*
Residential Houses*

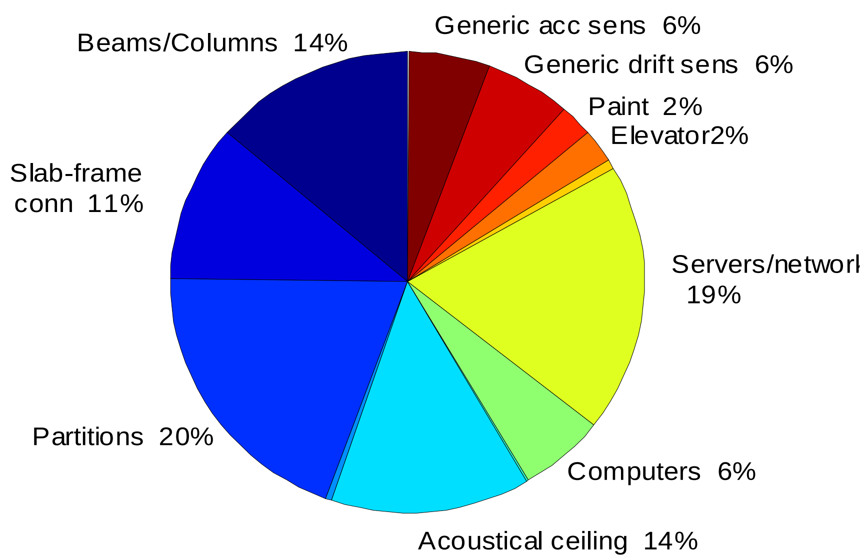
**Group 3**
Entertainment Parking

**Group 4**
Hospitals Research Labs

*Some outliers exist



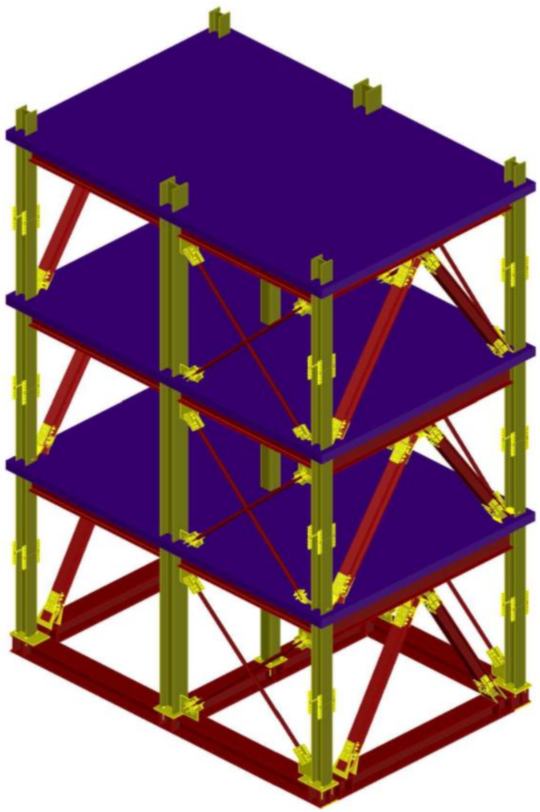

Khakurel, Dhakal et al 2019



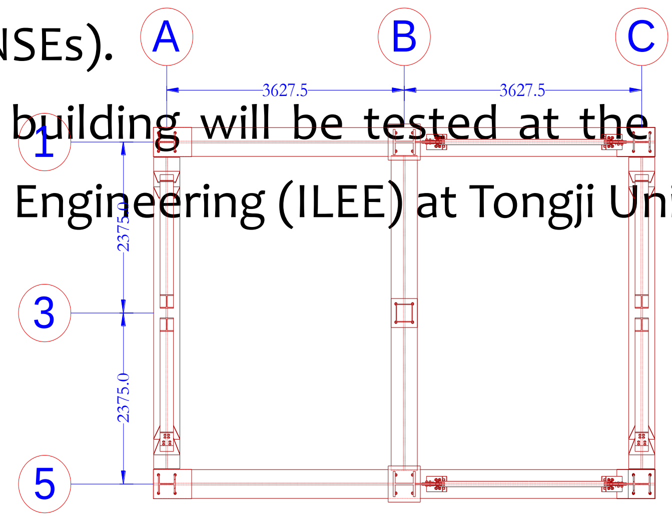

Bradley, Dhakal et al 2009

# INTRODUCTION

- The **Rc** ... JST) project is aimed at enhancing the seismic resilier ... ; and validating low-damage design concepts for structu ... ts (NSEs).
- A thre ... teel building will be tested at the International Joint R ... ıake Engineering (ILEE) at Tongji University.



3D View




Floor Plan

# SCOPE

- The objective of testing the NSEs is to *investigate and validate the seismic performance of acceleration and drift-sensitive NSEs, encompassing typical and low-damage design concepts, under realistic seismic demands resulting from dynamic interaction with the structural system.*

| **Non-Structural Element** | **Installation Location** |
| --- | --- |
| Suspended Ceilings | $2^{nd}$ & $3^{rd}$ Floor |
| Partition Walls | $1^{st}$ Floor |
| Precast Cladding Panels | $2^{nd}$ & $3^{rd}$ Floor |
| Curtain Wall Glazing | $2^{nd}$ & $3^{rd}$ Floor |
| Fire Sprinkler Piping | $2^{nd}$ & $3^{rd}$ Floor |

# LOADING

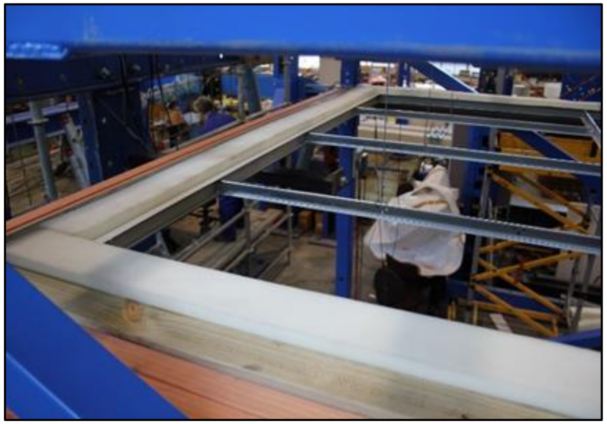
- The test structure will be subjected to unidirectional & bidirectional horizontal shaking with ground motions corresponding to the design-basis (10% in 50 years) and maximum considered earthquake (2% in 50 years) intensity levels.
- The set of prospective ground motions will include normal-directivity, near-field forward-directivity (pulse-like), and long duration subduction ground motion records.

# SUSPENDED CEILINGS

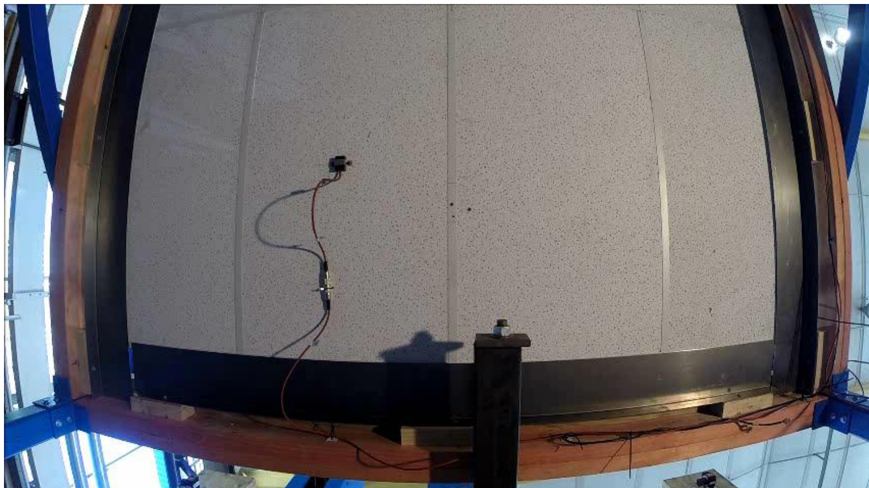
- Two variants of suspended ceilings will be tested:
  - Perimeter-Fixed & Fully-Floating

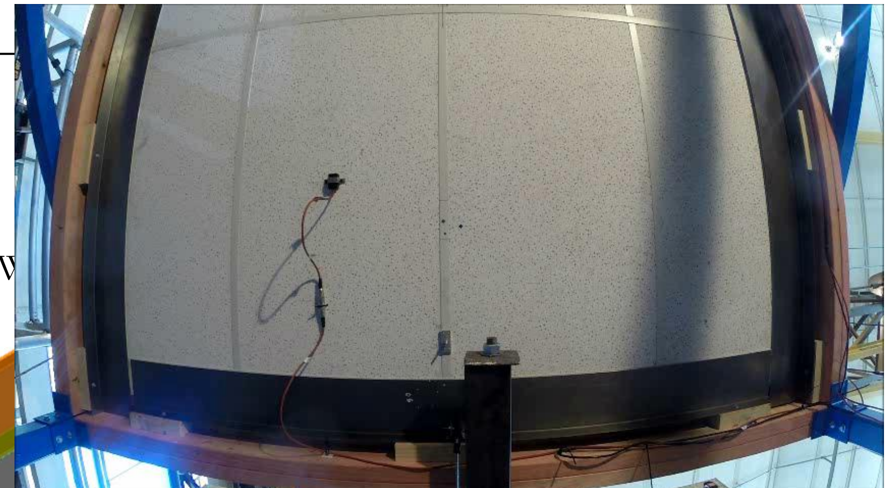

Perimeter-Fixed


Fully-Floating


Fully-Floating with Isolation Foam

# SUSPENDED CEILINGS






Without isolation foam
Ground motion: Northridge 1048-0.5
PFA: 0.25 g
Peak ceiling grid acceleration: 9.5 g (impact)
Peak ceiling relative displacement: 116 mm

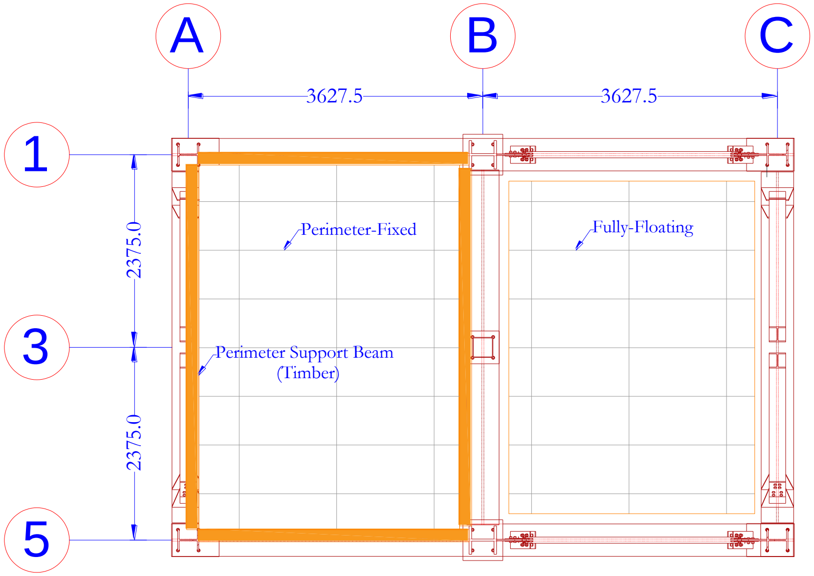
With isolation foam
Ground motion: Northridge 1048-0.5
PFA: 0.26 g
Peak ceiling grid acceleration: 0.53 g
Peak ceiling relative displacement: 4.9 mm

Fully Floating Ceiling

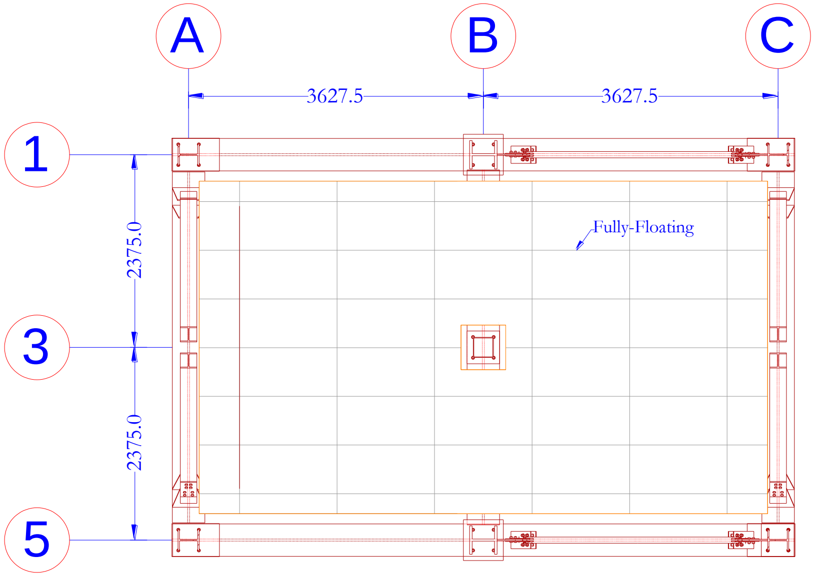
# SUSPENDED CEILINGS

- The objectives are:
  - To validate and illustrate the low-damage performance of fully-floating ceilings compared to the traditional & damage-prone perimeter-fixed under the same floor acceleration demands.
  - To assess the displacement response of fully-floating ceilings and the efficacy of the isolation material in restraining its displacements.

# SUSPENDED CEILINGS



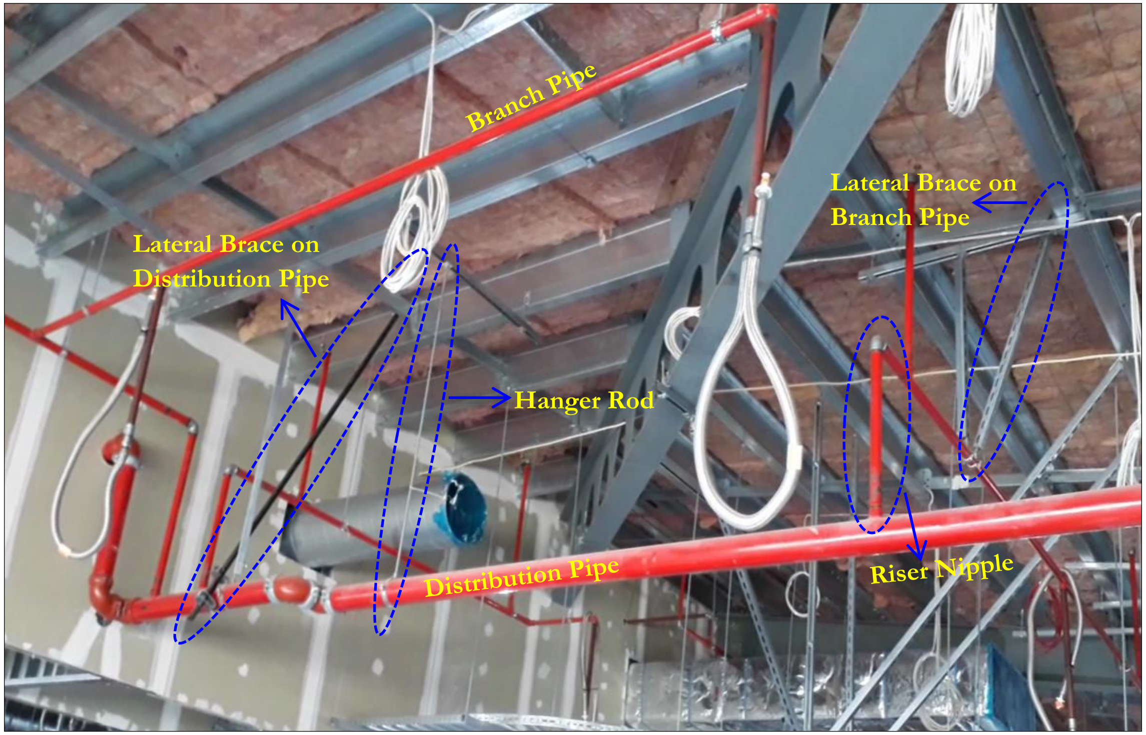

Plan View - Floor 2

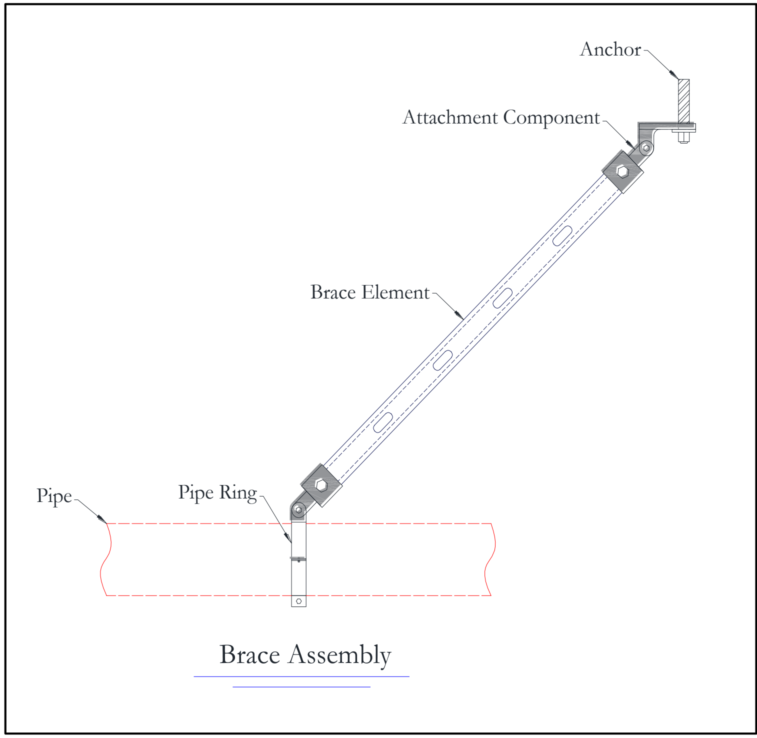



Plan View - Floor 3

# FIRE SPRINKLER PIPING SYSTEMS

- The piping systems will have different configurations on the two floors to investigate the influence of different details on their seismic performance.

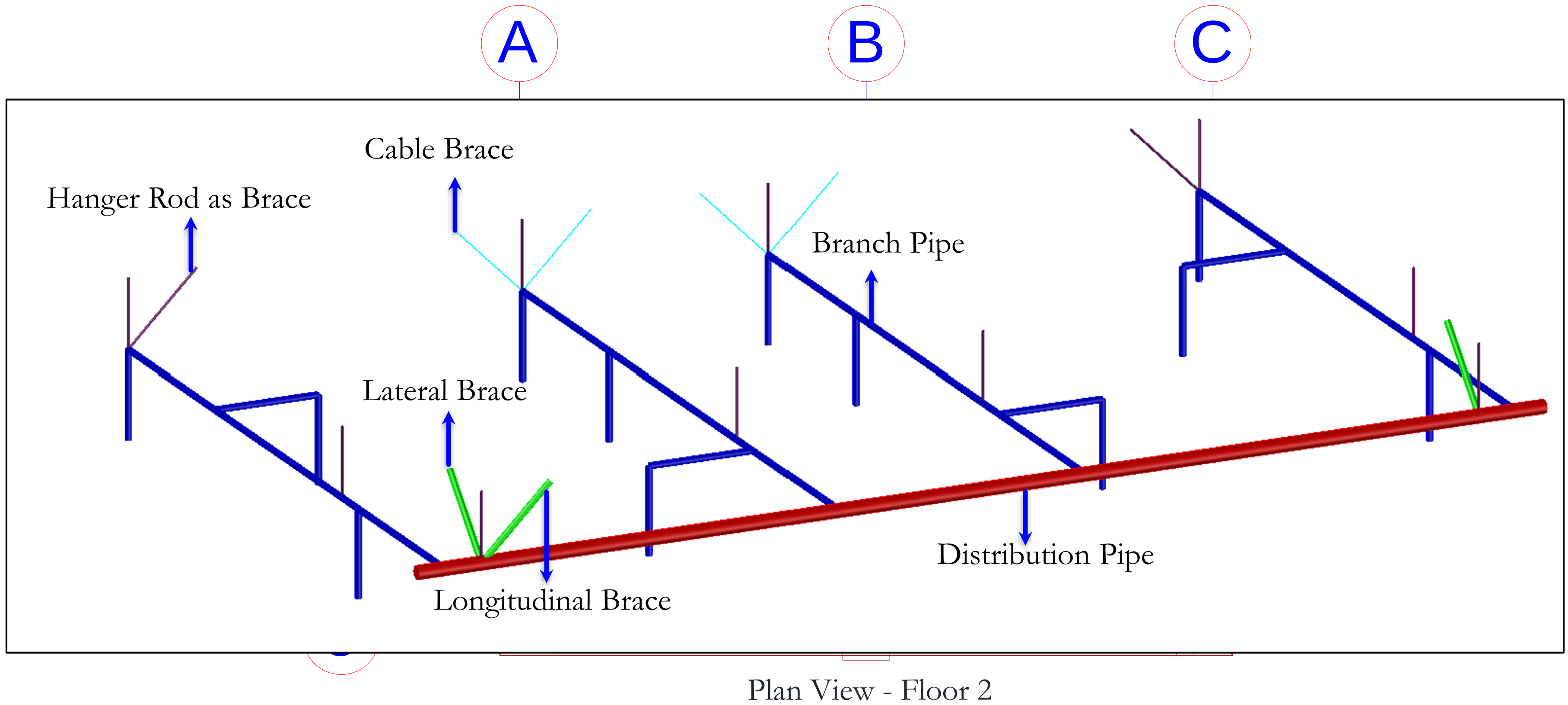


# FIRE SPRINKLER PIPING SYSTEMS

- The objectives are:
  - To investigate the performance of:
    - Typical brace assembly (brace element & attachment components), hanger rods and their anchors.
  - To investigate the displacement demand on long distribution pipes (> 6m), and the riser nipples which branch off the distribution pipes to supply water to the branch pipes.
  - To investigate the displacement demand on long branch pipes (> 6m) and the efficiency of hanger rods (10mm) and steel cables (wires) as bracing in restraining the displacement demands on the branch pipes.
  - Investigate the vulnerability of riser pipe to damage due to inter-story drift.

# FIRE SPRINKLER PIPING SYSTEMS



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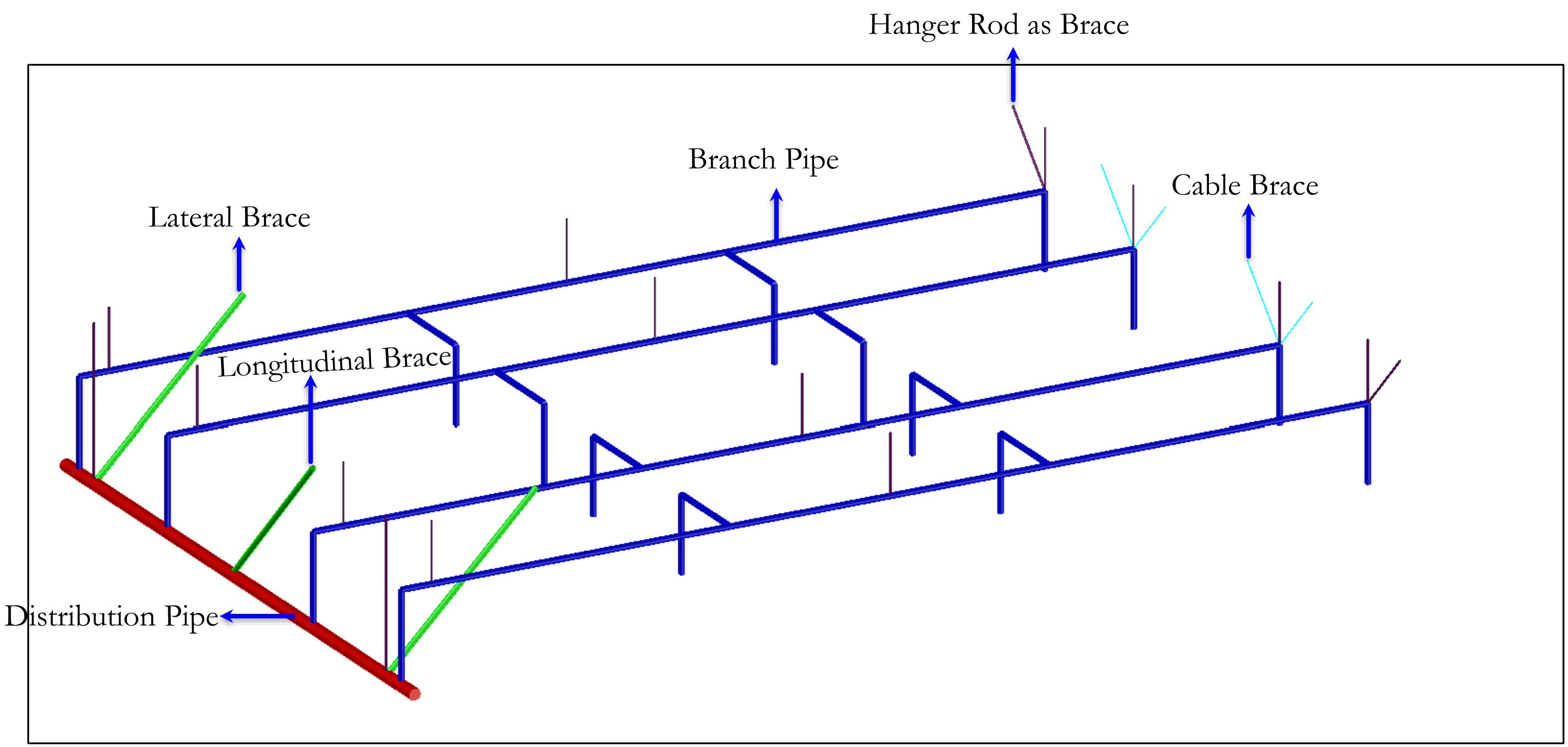
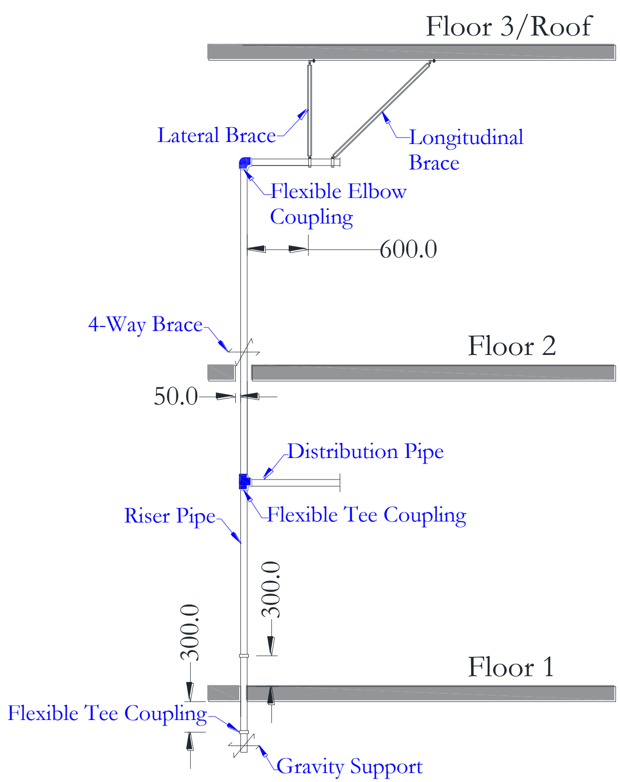
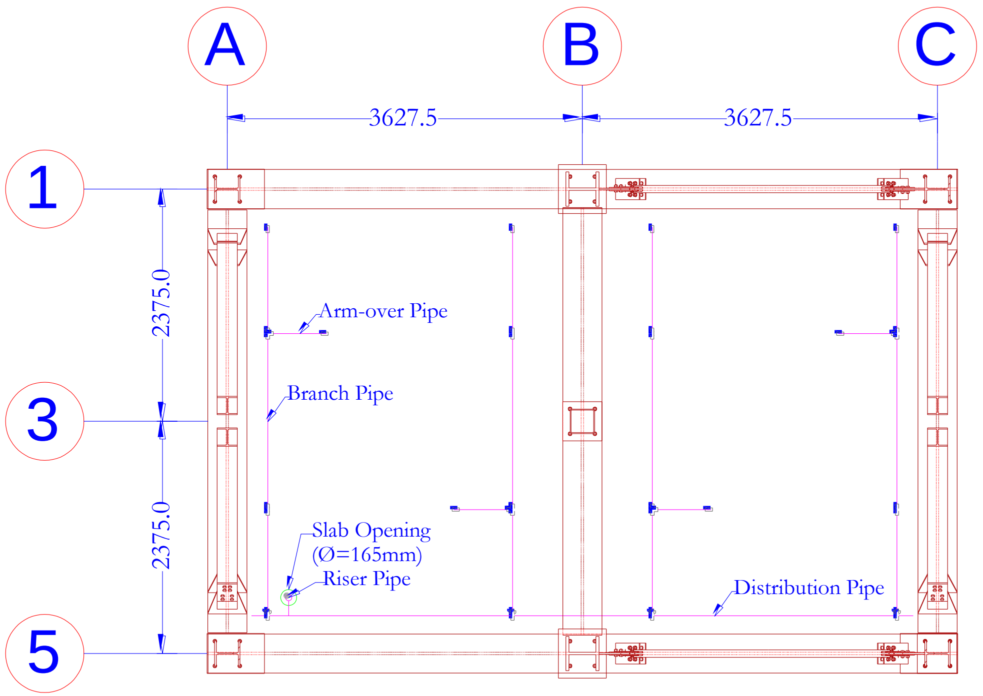


# FIRE SPRINKLER PIPING SYSTEMS

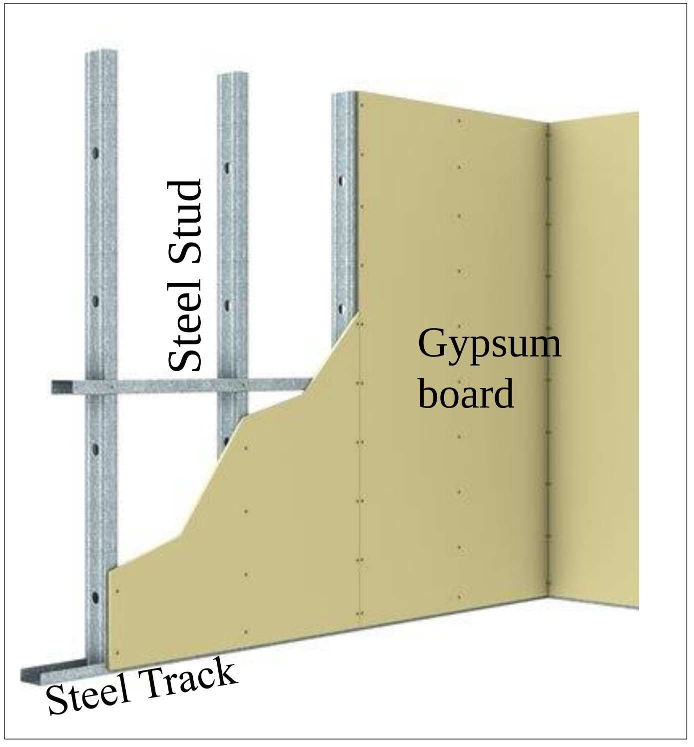



Plan View - Floor 2

# INTERNAL PARTITION WALLS

- Steel-Framed Internal Partition Walls



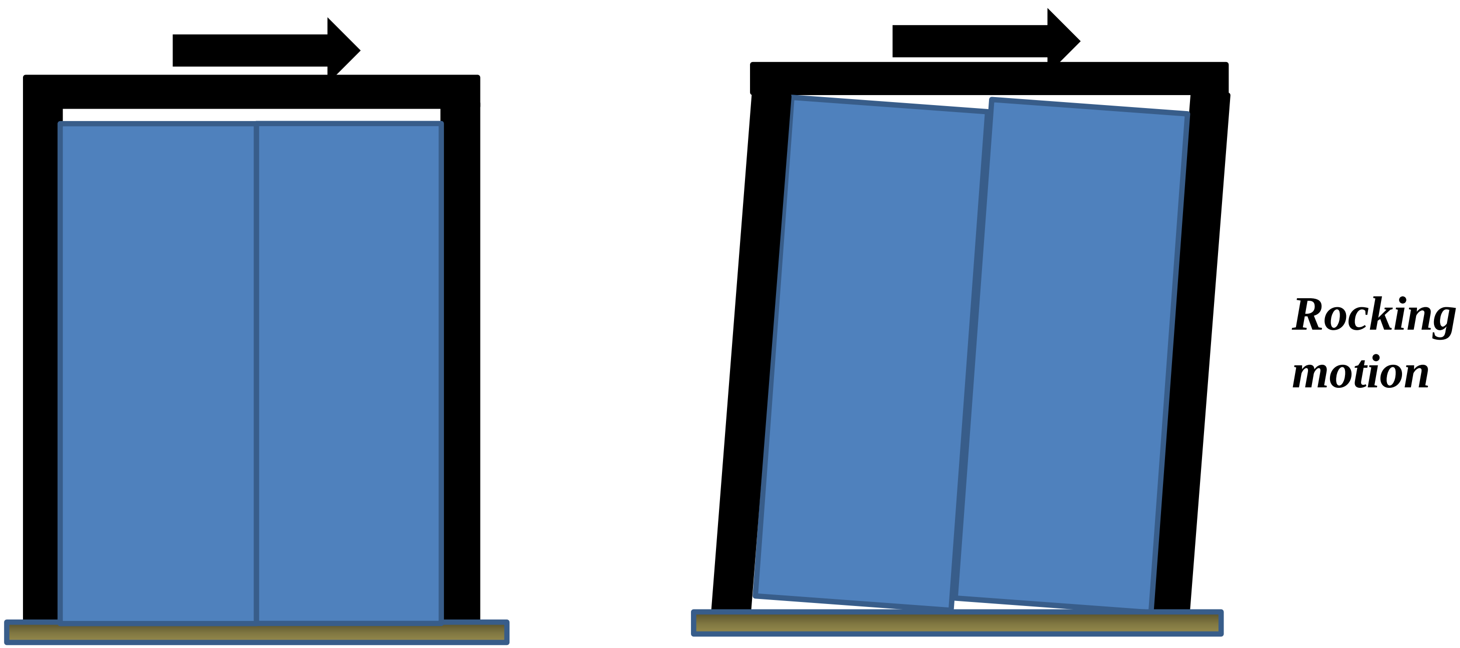

Gypsum boards are screwed to the steel studs

The top and bottom steel tracks are anchored to the top and bottom floor, respectively.

Steel-Framed Internal Partition Wall

# INTERNAL PARTITION WALLS

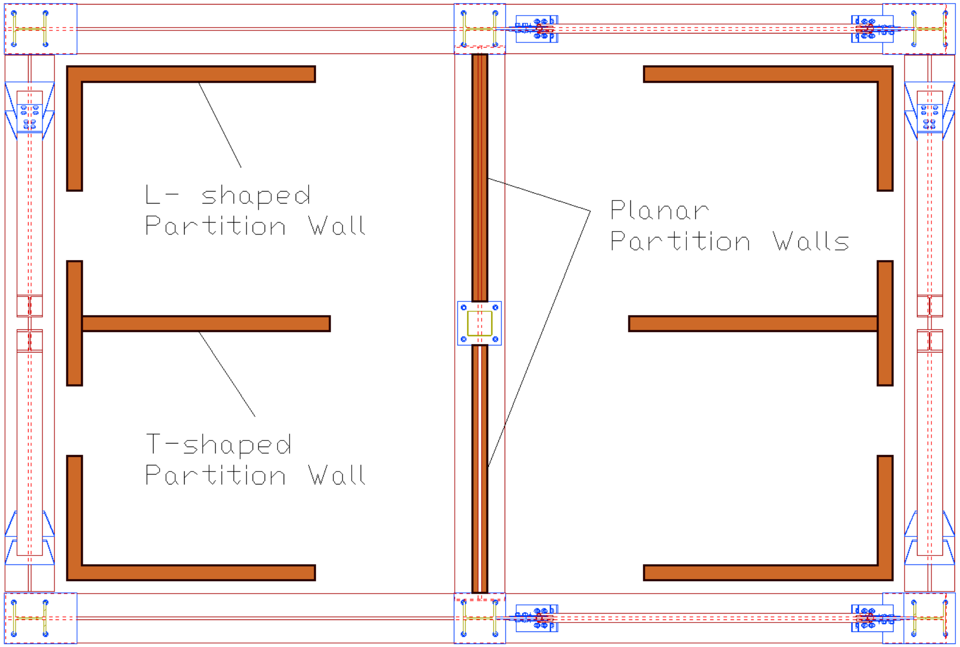
- Steel-Framed Internal Partition Walls with 'low-damage' rocking motion detailing will be installed on the first floor of the test structure




Schematic diagram of intended behavior of 'low-damage' partition walls

# INTERNAL PARTITION WALLS

- The objective is:
  - To investigate the seismic resiliency of the low-damage details of the partition walls under uni-directional and bi-directional shaking.

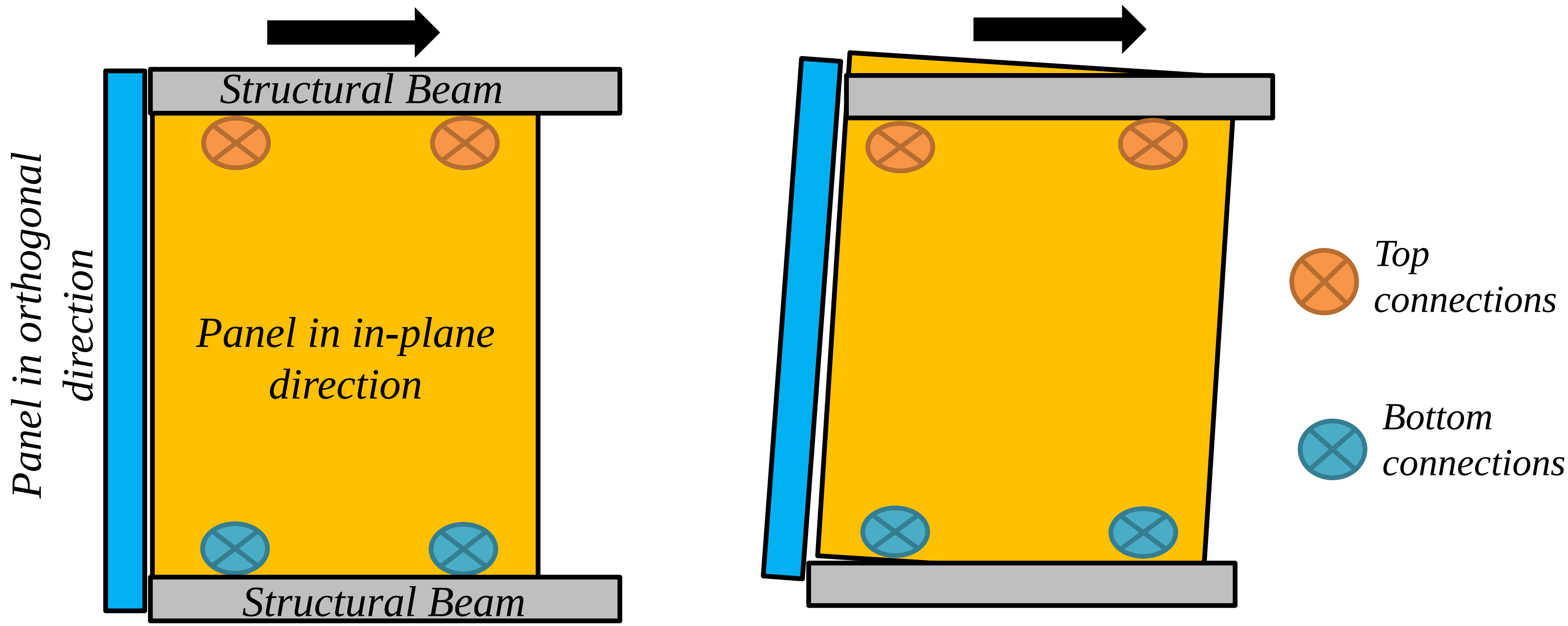



Plan View of Partition Walls on the First Floor

- T-Configuration
- L-Configuration
- Planar Configuration

# PRECAST CLADDING PANELS

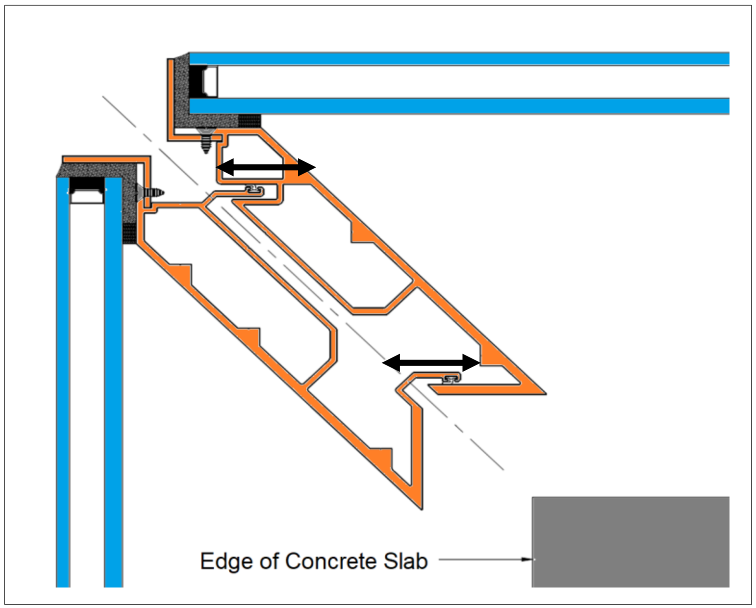
- Precast Cladding Panels with 'low-damage' rocking motion detailing will be installed at corners of the test structure on the second and third floor



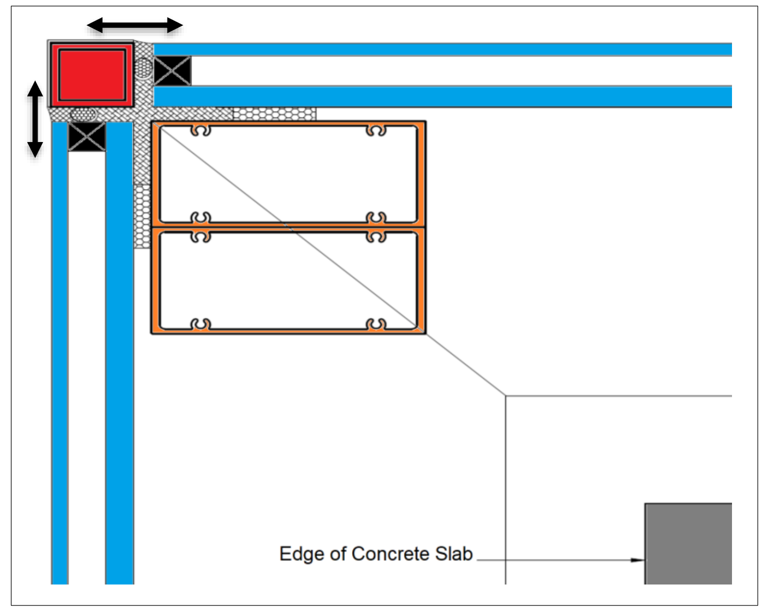

Schematic diagram of intended behavior of 'low-damage' Precast Cladding Panels at a building corner

# GLAZED CURTAIN WALLS

- Glazed Curtain Walls with two different 'low-damage' corner detailing will be installed at corners of the test structure on the second and third floor




a) Sliding Mechanism (Plan)



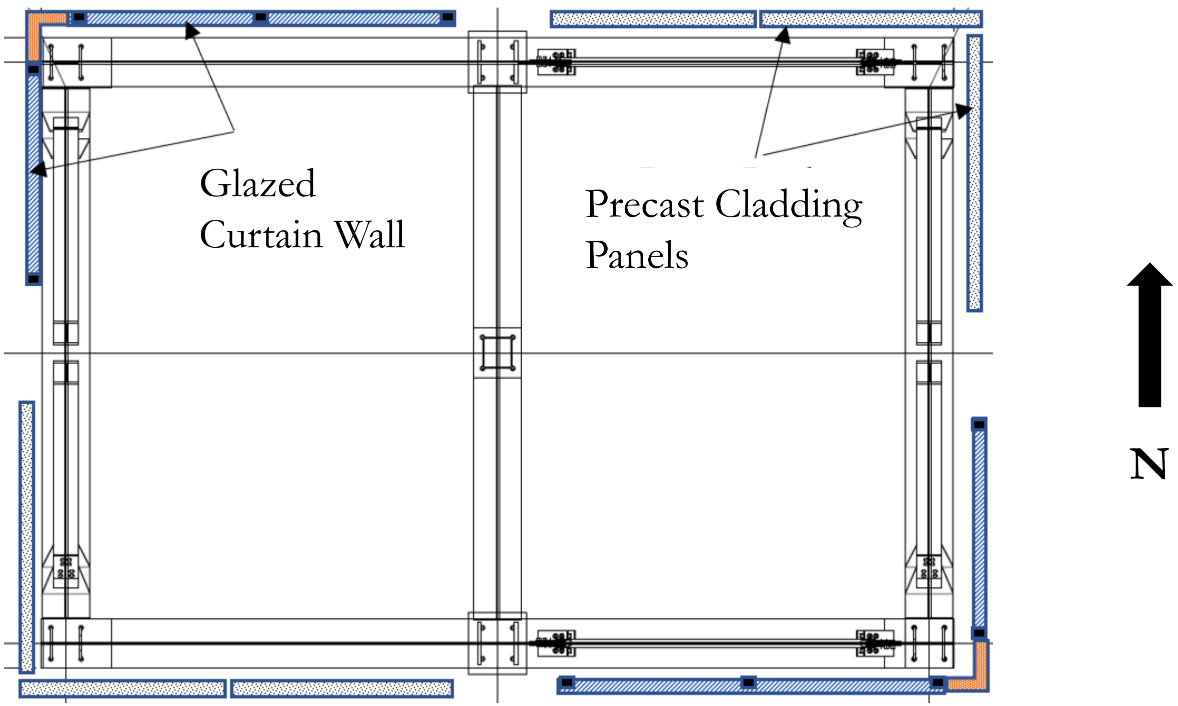

b) Sacrificial Mechanism (Plan)

Corner details of Glazed Curtain Walls

# PRECAST CLADDING PANELS AND GLAZED CURTAIN WALLS

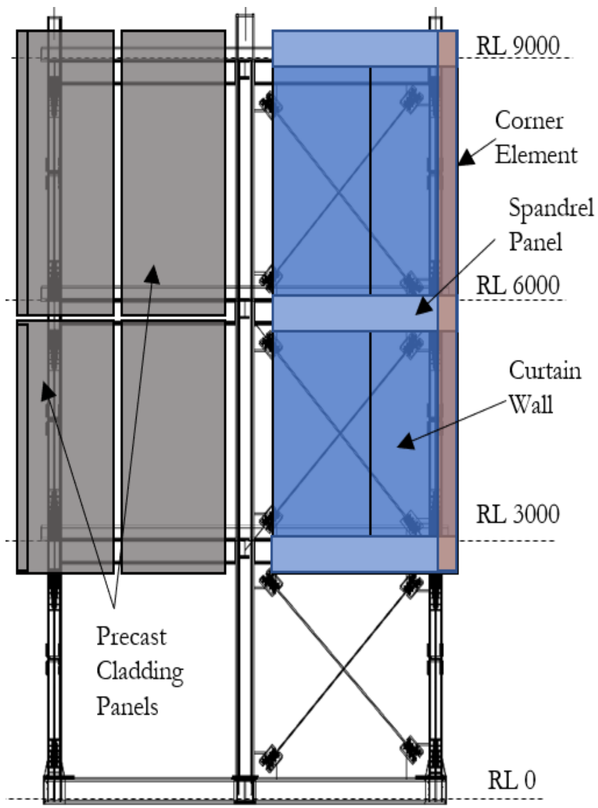
- The objectives are:
  - To investigate the in-plane and out-of-plane seismic performance of low-damage connection details of precast cladding panels under uni-directional and bi-directional shaking.
  - To investigate the compatibility of the precast cladding panels at the corners of the building under uni-directional and bi-directional shaking.
  - To investigate the seismic performance of low-damage corner details of Glazed Curtain Walls under uni-directional and bi-directional shaking.

# PRECAST CLADDING PANELS AND GLAZED CURTAIN WALLS

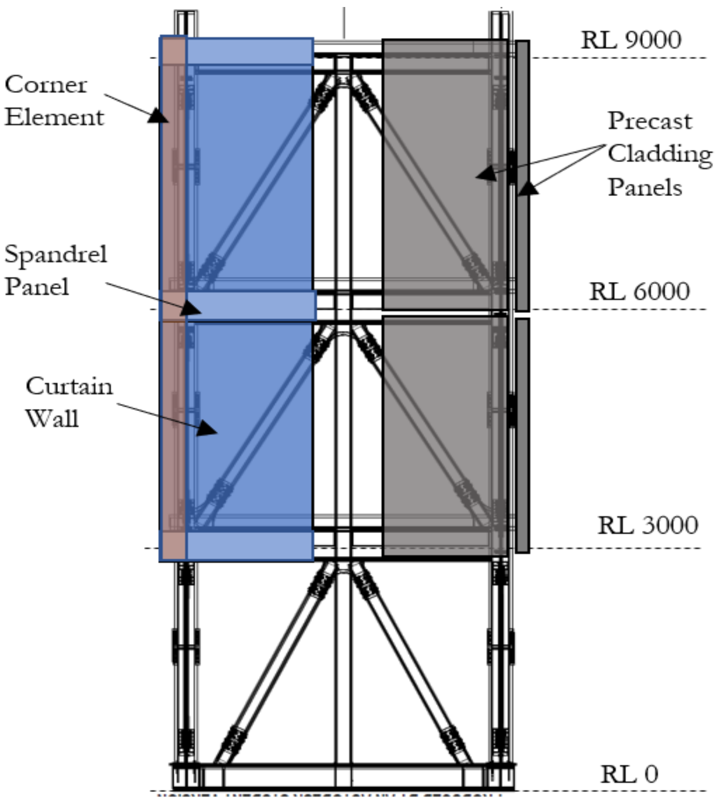



Plan View

# PRECAST CLADDING PANELS AND GLAZED CURTAIN WALLS




a) South Elevation




b) East Elevation

# INSTRUMENTATION

- A detailed instrumentation plan, for each component, is being designed.
- To measure different response parameters of interest, the following instruments will be used:
  - Accelerometers
  - String pots
  - Displacement potentiometers
  - Load cells
  - Camera/Video camera

# CONCLUSIONS

- An overview of plans for a shake table test of a three-story building at the International Joint Research Laboratory of Earthquake Engineering (ILEE) at Tongji University is presented.
- The testing plan includes acceleration and drift-sensitive non-structural elements distributed across the height of the steel framed building.
- This testing will lead to an enhanced understanding of the seismic behaviour of NSEs in New Zealand which is essential to improving the overall performance of buildings subjected to earthquake events.

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- Bradley, B. A., Dhakal, R. P., Cubrinovski, M., MacRae, G. A., and Lee, D. S. (2009). "Seismic loss estimation for efficient decision making." *Bulletin of the New Zealand Society of Earthquake Engineering*, 42(2), 96-110.
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- Pourali, A., Dhakal, R. P., MacRae, G., and Tasligedik, A. S. (2017). "Fully Floating Suspended Ceiling System: Experimental Evaluation of Structural Feasibility and Challenges." *Earthquake Spectra*, 33(4), 1627-1654.

# QUESTIONS

Thank You !